DOES THE INVOLVEMENT OF "GREEN ENERGY" INCREASE THE PRODUCTIVITY OF COMPANIES IN THE PRODUCTION OF THE ELECTRICITY SECTOR?

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ABSTRACT

This article evaluates the production possibilities of the electricity sector in selected EU countries. The estimates for production functions are based on the financial data of individual companies in the selected sector. The analysis was based on a linearized version of the two-factor Cobb-Douglas production function, which was subsequently modified to compare productivity results by company size and country. The countries were selected based on the results of a cluster analysis. The cluster analysis was performed using aggregated data on the shares of energy sources in production in the electricity sector. The results show that companies from countries with a high share of renewables (such as Denmark) perform the worst in terms of total productivity. Furthermore, it was found that large companies have significantly higher productivity when compared to their smaller competitors.

KEY WORDS

energy industry, productivity, Cobb-Douglas function, EU, cluster analysis

JEL CODES

D240, Q400, O130, C380, C320

1 INTRODUCTION

When it comes to energy sources, there is general pressure to use renewables. The decline in the popularity of "traditional" energy sources (non-renewable) is due to two reasons. The first is the limited reserves of fossil fuels and uranium. An estimation of when fossil fuel reserves will be depleted is very uncertain, and is therefore a topic that is constantly discussed. According to Speirs et al. (2015), uncertainty stems from five different areas. These include the uncertainty associated with inaccurate estimates of the volume of resources and reserves, uncertainty of technological progress, economic aspects, and the external environment in the

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form of national and international energy. The last area is the sustainability of fuels in the context of climate change legislation. Although it is not possible to completely eliminate these uncertainties, it is better to know their source and take them into account.

The second problem associated with non-renewable resources is carbon dioxide (CO_2), which is released into the air when fossil fuels are burned. Barbir et al. (1990) pointed out the problem of pollution. They identified populations, fauna, flora, agricultural production, the aquatic ecosystem, buildings, and air as the main areas where fossil fuel pollution has a negative effect. Mudway et al. (2020) mention that air pollution increases the number of people with respiratory disease, cardiovascular disease, diabetes, cancer, and dementia. In 2017, they estimated that pollution contributed to at least 5 million premature deaths. Pollution also accelerates natural processes that destroy various types of materials due to corrosion (Spezzano, 2021). Lanzi et al. (2018) estimated that the economic cost of inaction on air pollution will climb to 1% of world GDP by 2060. Increasing concentrations of CO_2 in the air are also directly related to climate change. The climate changes constantly and at relatively regular intervals during the Earth’s existence. However, in the last few decades, the Earth has been warming for the first time in history due to human intervention. The consequences of climate change are discussed in more detail by van Aalst (2006). Air pollution is mostly associated with fossil fuels. Saidi and Omri (2020) write in their work that nuclear power generation together with renewable energy in OECD countries reduces CO_2 emissions in the long run. But across the world, there is a negative attitude towards the construction of nuclear power plants due to the experience of nuclear accidents. Danzer and Danzer (2016) dealt with the long-term effects of the Chernobyl accident on the local population.

Above mentioned risks are increasingly encouraging the world to use renewables in energy production, as they are associated with low CO_2 production. According to Dincer (2000), there is a direct relationship between the use of renewable resources and long-term sustainable growth. One of the key elements in achieving energy, economic and environmental benefits is the need to support research and development in renewable energy technologies. The growing share of renewables in energy production is also supported by the spillover effect analyzed by Shahnazi and Shabani (2020). Their study of a sample of EU countries between 1995 and 2016 concluded that increasing the share of renewable energy production in neighboring countries leads to an increase in renewable energy production in the monitored country. The effect is mainly due to the mechanism of disseminating knowledge, learning, and imitating successful policies. If renewable economies are successful, it is likely that this trend will gradually spread.

1.1 Theoretical Background

Since the creation of the EU, energy has been one of the key areas for future development for member states. The proof is that two of the three communities that created the EU were energy – the European Coal and Steel Community and the European Atomic Energy Community. Over the years, the EU has been actively developing common energy plans and ambitious targets. The current European strategy for 2021–2030 supports reducing greenhouse gas emissions by 40%, increasing the share of energy consumption from renewable sources to 27% and increasing energy efficiency by at least 30%, all compared to 1990 levels. Energy efficiency is the ratio of energy inputs to outputs and is closely linked to the energy production process and, in the long run, to economic growth. The issue of energy efficiency is analyzed, for example, by Rajbhandari and Zhang (2018) and Vlontzos et al. (2014). Vlontzos et al. (2014) in their research focusing on the impact of subsidies in the field of energy efficiency of EU countries in 2001–2008 found that many Eastern European countries achieve low efficiency due to low levels of implemented technologies in the production process. Likewise, energy efficiency differs significantly between the new and old member states. An analysis of energy subsidies in EU countries for the period 2008–2018 was performed by Badouard and Altmann (2020). According to their results, subsidies for renewable energy increased by approximately 232% during the period under review. Badouard and Altmann (2020) also focused on an analysis of global subsidies for renewables and found that the EU 27 region subsidizes renewables the most with € 73 billion, followed by Japan with € 15 billion and the United States with € 9 billion. Connolly et al. (2016) focused their research on the EU's long-term goal of 2050, which is to become a fully dependent region based only on renewable energy, by presenting a scenario consisting of nine steps to achieve the set goal. They emphasized that research should be seen as a source of impact, not as a binding path. The results of their study suggest that achieving 100% renewables would increase total annual energy costs by 12% (compared to fossil fuels), but this radical change in technology would increase domestic investment leading to new job creation. Number of new jobs is estimated at up to 10 million. Despite the higher costs, this scenario would have a positive effect on the EU economy as a whole. Although several of the required technologies in connection with a given scenario can already be implemented, the authors suggest that the transition to 100% renewable resources largely depends on the capabilities and wishes of politicians and society.

Alataş et al. (2021) used data for the period 2000–2017 for energy and material productivity in the EU 28. Using a modified Cobb-Douglas production function, they concluded that while increasing energy productivity in the transition to a carbon-neutral economy by 2050, increasing material productivity should also be encouraged. In their analyses of productivity, they also found that technological advances increased both of these productivities. In relation to energy productivity, the research of Wan et al. (2015) can also be mentioned, where again using a linearized Cobb-Douglas production function, they analyzed data from the energy sector of the EU 15 in the period 1995–2005. Wan et al. (2015) found that promoting competition and disseminating knowledge stimulates trade and leads to higher energy productivity. Furthermore, countries with a higher dependence on trade have seen higher growth in energy productivity, so trade facilitation can improve energy efficiency across countries.

Radmehr et al. (2021) examined the relationship between economic growth, carbon emissions and energy consumption between 1995 and 2014 for EU countries. Rahman et al. (2020) similarly concluded in their work that there is not only a direct relationship between consumption and economic growth, but there is also a positive relationship between energy production and economic growth. These articles seek to provide empirical results that help policy makers to design adequate environmental and energy policies to meet the EU's economic development and sustainability goals. Research suggests that increasing energy productivity supports the achievement of the EU's goals, and increasing the share of energy from renewable sources increases economic growth and promotes a cleaner and healthier environment not only for the citizens.

1.2 Motivation and Contribution

The research carried out so far has typically relied on aggregated data for the whole energy sector (NACE code D). However, the use of this data aggregates the results of activities not only of energy production companies, but also, for example, of companies engaged in energy trade and distribution. Unlike other studies, this article focuses only on the financial data of companies within generation in the electricity sector (NACE code 35.11) in selected EU countries.

Based on the decisions of the EU's joint policies, but also thanks to the efforts of special interest groups, there is constant pressure to increase the share of renewable resources. The use of renewable energy sources generally has a longer payback period, and their implementation can be difficult at first. Therefore, the governments of individual countries use many different subsidy programmes in order to achieve sustainable development with regard not only to the economic aspect, but also with regard to the natural environment. However, a ”forced” shift to a higher share of renewables can have an impact on business productivity. It has not yet been clearly demonstrated whether this effect will be positive or negative. The main aim of this article is to find out whether those countries with a higher share of renewable resources are also the ones in which companies are the most productive.

The results of a cluster analysis will be used to select the representative countries for which the production function will be estimated. The countries will be clustered based on the share of the individual types of energy involved in electricity generation. From each cluster, one representative country will be selected according to the values corresponding to the average values of the cluster and with regard to the availability of the data needed to estimate the parameters of the production functions. In addition to comparing productivity by country, thanks to the micro dataset productivity will also be evaluated by company size.

2 METHODOLOGY AND DATA

Macro-level data of individual countries were obtained from the official European database Eurostat (under the name Complete energy balances – Gross electricity production). Micro-level data of individual companies were obtained from the international database Orbis. Due to the fact that the Orbis database contains the most current and complete data available from 2016, analyses at the level of macro data also focused on data from 2016.

Macro-level data for the cluster analysis represent cross-sectional data in the form of shares of energy types according to their share of total electricity production for EU 27. The original values were measured in GWh, but for the sake of an objective comparison of countries, the values were converted into shares. Each energy source (variable) is expressed as a percentage of the total electricity production. Therefore, the variables take values from the interval 1–100% with the sum of the values of all variables for each country always being equal to 100%. A list of variables used in the cluster analysis, including descriptive statistics, is included in Tab. 1.

Seven variables were used for the analysis: fossil fuels, biofuels, hydro energy, wind energy, solar energy, geothermal energy, and nuclear energy. Tab. 1 provides descriptive statistics in the form of minimum, maximum, average, and median values for all the EU 27. At least a small share of fossil fuels is used by each country, as well as biofuels and wind energy, because the minimum value of the variables is higher than 0%. On the other hand, there are countries that do not use hydro, solar, geothermal or nuclear energy in the production of electricity. According to the average values, it is clear that the largest share of electricity production in EU countries is represented by fossil fuels together with biofuels. It is also clear that even in 2016, significant differences in the energy mix persist between EU countries.

Several groups (clusters) of countries were created using the cluster analysis. For each cluster, one typical representative of this cluster was then selected, and an estimate of the production function was performed for it based on the individual data of the companies in the selected country. The production analyses were based on the linearized Cobb-Douglas production function:

$$\ln y_i = \alpha + \ln f(x_i, \beta) + \epsilon_i, \tag{1}$$

where y_i is the product of each unit i and $i = 1, \ldots, I$; x_i is a vector of inputs, β is a vector of parameters estimated, $\alpha = \ln \beta_0$ (i.e., intercept), ϵ_i is error term. Two variables related to the transformation process were included in the models, namely the labor and capital factor.

In this case, the product is represented by added value, labor is represented by the cost of employees and in the case of capital, its real (physical) version is approached, which is represented by, for example, machines, buildings,

Tab. 1: Categories for the cluster analysis and descriptive statistics (%)

Category and variables	Min	Max	Average	Median
Fossil fuels (solid fossil fuels; manufactured gases; natural gas; oil and petroleum products; oil shale and oil sands; peat and peat products)	0.86	84.01	37.08	28.45
Biofuels (renewables and biofuels; primary solid biofuels; pure biodiesels; other liquid biofuels; biogases)	8.97	49.74	28.57	25.74
Hydro energy (hydro; tide, wave, ocean)	0.00	38.63	12.06	9.99
Wind energy	0.01	26.99	6.43	4.49
Solar energy (solar thermoval; solar photovoltaic)	0.00	12.87	2.17	1.31
Geothermal energy	0.00	1.60	0.07	0.00
Nuclear energy	0.00	60.83	13.61	0.00

materials, licenses, or know-how. Capital is therefore derived from the financial statements of companies, where the values of total assets are monitored. All values from the Orbis database are in thousands of euros.

In the case of two-factor Cobb-Douglas production function, three parameters are estimated. These parameters are usually referred to as A, α, and β. A is the level of technology; α and β correspond to the elasticity of production to labor and capital, under the conditions $\alpha, \beta > 0$. The condition of a positive value also applies to parameter A.

The original production model (according to Equation 1) was further additively extended with artificial variables representing company size and country, in order to determine which countries and which types of companies are the most productive. In a similar way, it is possible to add variables representing the ratio of renewable and non-renewable energy sources in a given country.

Due to the fact that it is possible to use a linearized version of the Cobb-Douglas production function (see Staňková, 2020; Staňková and Hampel, 2019, 2021) the parameter estimates were performed via the OLS method. Similarly to Zámková and Blašková (2013) and Adamec and Střelec (2012), t-tests were used to verify the statistical significance of the estimated parameters of the Cobb-Douglas production function model. The F-test was used to verify the significance of the model itself. Variance inflation factor (VIF) values were used to identify possible multicollinearity. The assumption about the correct specification of the model was checked using a RESET and LM tests. The White and Breusch-Pagan tests were used to detect possible heteroskedasticity of residues. Finally, the assumption of the normal distribution of the error term was verified using the Chi-square test. More detailed information about the assumption verification of regression analysis models can be found in Gujarati and Porter (2017).

In order for the estimates to be as consistent as possible, a requirement was introduced that the estimates of production functions be based on values from at least 30 companies. The following countries did not meet this requirement: Croatia, Ireland, Lithuania, Latvia, Luxembourg, the Netherlands, and Greece. Therefore, these countries were intentionally omitted from the estimation of production functions and were not taken into account as a possible representative of the cluster.

All of the above-mentioned calculations were performed in the Matlab computational system (version 2021a) and Gretl software (version 2021a).

3 RESULTS

The results of the differently set approaches to the calculation in the cluster analysis were similar. However, from a factual point of view, on closer examination, the Ward method seemed to be the most plausible, as in Staňková and Hampel (2017) and Stojanová et al. (2018). Fig. 1 shows a dendrogram, which identifies five clusters using a cut at a distance of 0.58. According to the dendrogram, the most numerous group is cluster 4 (i.e. red in Fig. 1), which includes seven European countries. On the contrary, cluster 3 (blue) has the fewest members. It is interesting to note that at first sight these are not clusters of countries with a close geographical location. However, individual clusters can be described from the point of view of the representation of energy sources in the production of electricity. The average values of the variables for each defined cluster are in Tab. 2, including the values for the countries that are selected to estimate production functions.

Cluster 1 (purple) includes Estonia, Cyprus, Malta, the Netherlands, and Poland. These countries have the highest share of fossil fuels in electricity generation in the EU. According to Tab. 2, the average value of fossil fuels for the whole of cluster 1 is 76.79%. The second largest share is represented by biofuels with 14.46%. Other renewable energy sources represent only a small share of the entire electricity production. The Netherlands is the only state in cluster 1 that uses nuclear energy to generate electricity. Cyprus and Malta have one of the highest values of fossil fuels, and also have the least subsidies for energy from renewable sources (Badouard and Altmann, 2020). Poland is another country with a high share of fossil fuels, which is justified by their large coal reserves and resources. The amount of coal ranks it among the 10 countries with the largest reserves and resources of coal in the world. Poland was chosen as the representative of cluster 1 for two reasons. Poland with its mean values is close to the average values for the whole of cluster 1, see Tab. 2, and also due to the fact that, compared to the other countries in cluster 1, there is a sufficient number of companies with available data.

Cluster 2 (yellow) is made up of countries where fossil fuels still make up the largest proportion of electricity generation. According to Tab. 2, Greece, Ireland, Italy, Germany, Bulgaria and the Czech Republic produce an average of 49.55% of electricity from fossil fuels. The remaining production is supplemented by biofuels and nuclear energy. Nuclear energy in cluster 2 is represented only by the Czech Republic, Bulgaria and a smaller share of Germany. However, the national policies of all three countries have a tendency to expand nuclear energy in the coming years. For example, since the Velvet Revolution (1989) the Czech Republic has strived to be more ecological in the field of energy production. However, it tends more towards nuclear energy with two nuclear power plants currently in operation – Temelín and Dukovany. Despite the fact that the future of nuclear energy in the EU is very uncertain, it plays an important role in the energy plan of the Czech Republic. This plan even promotes the construction of new nuclear reactors, especially in connection with the end of operations in the Dukovany nuclear power plant. The Czech Republic was selected for the production analysis due to it having values close to the average values of cluster 2 (see Tab. 2).

Cluster 3 (blue) is represented by countries in which nuclear energy is a significant part of electricity generation, as can be seen in Tab. 2. These countries are Slovakia, France, Hungary, and Belgium. The countries that gave birth to the European Community believed that nuclear energy was the main path for development. Among them is France, where nuclear energy accounts for 60.83% of electricity generation. Another of the founding countries that has retained nuclear energy as its main source is Belgium. The rationale for the remaining states participating in cluster 3 has little potential for the use of other renewables. For example, limited or no access to water, or a lack of sunlight and poor wind conditions may be to blame. Due to the negative attitude in the EU

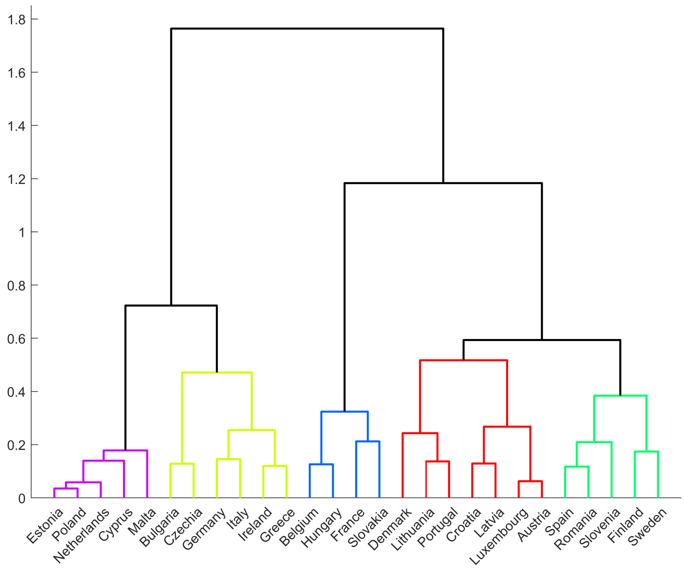

Fig. 1: Dendrogram with the five identified clusters

Tab. 2: Average values (in %) of variables for the individual clusters and selected representative countries

	Fossil fuels	Biofuels	Hydro energy	Wind energy	Solar energy	Geothermal energy	Nuclear energy
Cluster 1	76.79	14.46	0.34	4.36	3.41	0.00	0.63
Poland	75.44	16.47	1.38	6.64	0.07	0.00	0.00
Cluster 2	49.55	22.78	6.17	6.81	3.47	0.27	10.95
Czech Rep.	51.74	16.28	3.42	0.53	2.28	0.00	25.75
Cluster 3	21.15	19.22	6.47	2.69	1.68	<0.01	48.79
France	8.16	16.48	9.99	3.23	1.31	0.01	60.83
Cluster 4	19.76	45.26	23.82	10.10	1.04	0.03	0.00
Denmark	24.16	47.24	0.04	26.99	1.57	0.00	0.00
Cluster 5	19.42	33.77	18.84	5.90	1.37	0.00	20.70
Finland	14.75	42.28	16.13	3.13	0.02	0.00	23.69

towards nuclear energy, it may mean reducing the share of nuclear energy in the future in countries where it is possible to involve alternative sources in energy production. To estimate the production function, France is selected from cluster 3 as one of the countries that seeks to replace fossil fuels with a significant share of nuclear energy. Although France differs in some values from the averages in the cluster, it has shown another ecological path that can be followed in the future by other EU countries, including, the Czech Republic, Bulgaria and Germany.

Cluster 4 (red) is characterized by very low values for fossil fuels and high values for biofuels in combination with water and wind energy. Cluster 4 includes Austria, Luxembourg, Latvia, Lithuania, Croatia, Portugal, and Denmark. Cluster 4 has one of the largest shares of hydropower (see Tab. 2). This is probably due to the fact that most countries in cluster 4 have good access to the sea or a large number of watercourses. Luxembourg and Austria have one of the highest shares of hydropower in electricity generation. Both countries have favorable topographical conditions, and the use of hydropower is also of traditional importance for Austria. The historical development of hydropower in Austria has been underway since 1840. But Wagner et al. (2015) point out that another large expansion of hydropower in Austria could have a negative impact on river ecology and the morphology of watercourses, which is contrary to European legislation. However, from the given cluster, Denmark was chosen as the representative for estimating the production function, primarily due to a lack of data for other countries in the cluster.

Cluster 5 (green) is formed by a group of countries that have similarly low values for fossil fuels as cluster 4, but high shares of biofuel in combination with nuclear energy. Namely, Finland, Sweden, Romania, Slovenia, and Spain. With the exception of nuclear energy, cluster 5 is very close to cluster 4 in Tab. 2. The typical representatives of cluster 5 are the two Nordic countries – Finland and Sweden, which are known for their emphasis on the use of renewable resources, as demonstrated by the low proportions of fossil fuels. Sweden uses only 0.86% of fossil fuels to generate electricity and Finland 14.75%. Sweden's national energy plan states that it wants to become the world's first country with zero fossil fuel use by 2045. A similar vision is shared by other countries in clusters 5 and 4. However, Finland was chosen to estimate production functions because Sweden has available data for less than 30 companies.

In the first step, a common model according to Equation 1 was estimated for five selected countries. Estimates of the parameters (always statistically significant parameters) are recorded in Tab. 3. Based on the values of the individual parameters of the common model, it can be stated that the “typical” company operates at the level of increasing returns from scale and capital have a greater influence on the size of the product compared to labour.

Subsequently, the common model was extended by an artificial variable representing the country in which the companies are located. The results of this model, recalculated for each country, are also included in Tab. 3. Based on the results of this first modified model, it can be stated that companies in the Czech Republic have a higher total productivity factor value compared to other selected countries. From this point of view, Denmark and France are in the worst positions.

Tab. 3: Estimated parameters for common model and modified model with recalculated results for individual country

Model	$\hat{A}$	$\hat{\alpha}$	$\hat{\beta}$
Common	0.5160	0.1569	0.7644
Poland	0.5845	0.1576	0.7630
Czech Republic	0.6178	0.1576	0.7630
France	0.4649	0.1576	0.7630
Denmark	0.4470	0.1576	0.7630
Finland	0.5285	0.1576	0.7630

Given that it is the Czech Republic that has the lowest share of renewables and, conversely, France has the lowest share of fossil fuels and Denmark has the lowest share of nuclear energy (see Tab. 2), it can be assumed that there will be a negative link between the use of renewable energy sources and total factor productivity. If we adjusted the original model by a variable representing the share of renewable and non-renewable energy sources (calculated on the basis of Tab. 2), then the variable of renewable sources with a negative parameter (specifically −0.0013) and a variable representing non-renewable sources with a positive parameter (0.0044) would actually be significant in the model.

Tab. 4: Estimated parameters for second modified model with recalculated results by company size

Model	$\hat{A}$	$\hat{\alpha}$	$\hat{\beta}$
Small companies	0.5522	0.1515	0.7542
Medium-sized companies	0.5750	0.1515	0.7542
Large companies	0.8878	0.1515	0.7542

If we focus instead of the geographical area on company size, it is possible to create another modified model with an artificial variable representing company size. The results of recalculated parameters by company size are recorded in Tab. 4. This analysis showed that the level of technology is the highest in the case of large companies. In general, it can be state that with increasing company size, the total productivity factor increases.

Over 90% of the value-added (dependent variable) variability was explained by all the models mentioned. According to the verification test results, all models were correctly specified, and the residues showed the properties of a classical error term.

4 DISCUSSION

The Euclidean distance with Ward's method best divided countries into clusters. Based on the clarity and balance of the number of members, five clusters were interpreted. The countries in the clusters were sufficiently similar, although slight differences were found mainly in the distribution of shares between renewable energy sources. The cluster analysis identified cluster 1 as having countries with a fossil fuel share of over 75%. The countries in cluster 2 were very close to cluster 1, as these were countries where fossil fuels still accounted for the largest share. However, the share was in the lower range of 41–59%. These countries have further combined fossil fuels with renewables and nuclear energy. Cluster 3 connects countries that largely produce electricity from nuclear energy. Clusters 4 and 5 were formed by countries where biofuels contributed the most to electricity generation. The feature distinguishing clusters 4 and 5 was that countries in cluster 5 combined biofuels with nuclear energy, whereby countries in cluster 4 only combined biofuels with other representatives of renewable energy sources. The small distance between the two clusters was also indicated by the dendrogram (see Fig. 1). A common aspect of the countries in clusters 4 and 5 is the great potential for the use and expansion of renewable resources. This advantage is mainly provided by favorable geological conditions.

Parobek et al. (2016) dealt with a very similar topic. Their work focused on the use of renewable energy sources in total energy production and consumption in EU countries based on data from 2012. They used the same distance measurements using Euclidean metrics in combination with Ward's method. Their cluster analysis took into account variables that represented external influences, such as economic indicators and the availability of renewable resources in the country. They identified nine clusters in which significant similarities in member composition can be found compared to the results in this article. This highlights the fact that although this article focuses only on a selected part of the energy industry, it may be assumed that its results can outline the similarity of national energy sectors across EU countries. Even though Parobek et al. (2016) used an older and wider data set, they also included Cyprus, Malta, and Estonia in the same cluster as the countries with the lowest share of renewable energy sources in primary energy production. The grouping of Austria, Portugal, Sweden, and Finland also emerged as countries with the highest share of biomass use (here part of the biofuel variable). In the described work, the Czech Republic and Bulgaria are part of a similar cluster with an average share of the use of renewable resources, but below the average of biomass. By analogy, the Netherlands and Poland were included in the cluster with the lowest shares of renewable energy use, and Hungary and Belgium did not show any unique differences in the use of renewable energy sources, because both countries focus largely on nuclear energy. Based on EU regulations and strategic plans, it is possible to expect more intensive convergence of EU countries in the field of electricity generation in the future.

The production analysis included five countries representing the five identified clusters. The selection of individual countries was conditioned by two criteria. Firstly, a sufficient number of observations and the completeness of the data. Secondly, the values of the selected country correspond as much as possible to the average values of the cluster. The final selection included Poland, France, Finland, Denmark, and the Czech Republic.

The parameters of the elasticity of the output to the input factors indicate that in the electricity generation sector, capital always has a greater influence on the output, because the values of the parameter $\hat{\beta}$ estimates in all cases are significantly higher than the parameter $\hat{\alpha}$ estimates. The issue of returns to scale in electricity generation has so far been measured very rarely. Some older studies can be found, such as Smigel at al. (1974), Dhrymes and Kurz (1964) or Nerlove (1963).

Smigel et al. (1974) estimated the parameters of the production function of electricity generation in Pennsylvania in the period between 1956 and 1971 using the Cobb-Douglas function. However, they chose the average number of employees and the average number of hours worked as an indicator of the labor factor, the total installed capacity represented capital and the total amount of electricity produced in kWh represented the product. Despite these differences, our results came to a similar conclusion regarding the effect of labor and capital on total output. The smaller influence of the labor factor is probably caused by the high automation of the electricity generation process. Therefore, the workforce fulfills the function of supervision, maintenance, administration and similar matters related to operations. Smigel et al. (1974) add that labor demand increases in proportion to output and the number of production units in operation.

Nerlove (1963) chose the Cobb-Douglas functional form, whereas Dhrymes and Kurz (1964) leaned toward the CES production function in the analysis of steam power generation in the United States. In both cases, the chosen inputs were labor, capital and fuel. Nerlove (1963), Dhrymes and Kurz (1964) and Smigel et al. (1974) identified increasing returns to scale. In this respect, too, the productivity results of the selected countries in this article are in line with those of other countries. Unfortunately, no newer or older studies focusing on European countries are currently available, so it is not possible to make a closer comparison of the estimated parameters within the selected energy sector.

It is possible to state that if the selected countries had one unit of labor and capital, then the largest amount of electricity would be produced by the Czech Republic, followed by Poland, Finland, France, and the least by Denmark, see Tab. 5. Among the selected countries, the Czech Republic can be described as the most productive, because with the same number of inputs, it can produce the highest product. When monitoring the percentage increase in Tab. 5, Denmark took the imaginary first place, and the Czech Republic is last. The difference between countries can be explained by the different position on the total production curve.

Tab. 5: Calculation of production values for two levels of inputs for the models of selected EU countries

	$L = 1$ $K = 1$	$L = 2$ $K = 2$	**Change in %**
Czech Republic	1.5384	2.4590	159.8414
Denmark	1.3676	2.2882	167.3150
Finland	1.4491	2.3697	163.5291
France	1.3855	2.3061	166.4453
Poland	1.5051	2.4257	161.1654

Differences in national productivity are caused by various external factors, such as technological progress. The development of power plants using fossil fuels has been going on since the second half of the 19^{th} century. Nuclear power plants have been used since the middle of the 20^{th} century. During that time, some progress has been made in the area of electricity generation. Higher development in energy production in connection with both fossil fuels and uranium would then correspond to the results of Smigel et al. (1974), Nerlove (1963) and Dhrymes and Kurz (1964), who identified increasing returns to scale in the last century. At present, therefore, countries using fossil fuels or uranium (like Czech Republic) may have more technological development. However, thanks to the significant development of renewable energy sources in recent years, the technological progress of renewable energy sources could be currently more intensive.

Smigel et al. (1974) indicated that one of the most important factors in the technological progress of electricity generation is the large amount of installed capacity. However, the financial side of this problem must be considered. According to the IEA (2020), by 2019, wind energy with nuclear energy was one of the cheapest sources of electricity generation. In Denmark, for example, wind farms are capable of generating 1 MWh of electricity for $ 29.18 in terms of lifespan. For a similar lifespan of nuclear power plants, France produces 1 MWh for $ 30.65. Of the available values, India produces the cheapest electricity from coal at $ 70.54 per 1 MWh, and the lowest costs of producing electricity is in Mexico at $ 40.32 per 1 MWh. Kåberger (2018) also suggests in his study that renewable energy sources are in many cases cheaper than fossil fuels today. The fact that most renewables do not need fuel for their service reduces their costs and, as a result, depends only on initial and operating costs.

Unfortunately, there are currently no more comprehensive studies that approach the focus of this problem. The lack of studies can be expected due to the limited availability of data at the level of individual companies, and the second possible explanation is the fact that European electricity generation sectors are often characterized by only a handful of large companies and, conversely, a large number of medium and small enterprises. However, according to Černohorský (2015), this market structure does not create sufficient space for competition and thus lacks motivation to evaluate productivity or efficiency like in Staňková (2020) or Gaebert and Staňková (2020).

Thanks to the use of micro-data for individual companies, it was possible to find out not only the fact that companies from countries with the lowest share of renewable resources are the most productive, but also the fact that large companies have the highest total productivity, see Tab. 6.

Tab. 6: Calculation of production values for two levels of inputs by company size

	$L = 1$ $K = 1$	$L = 2$ $K = 2$	**Change in %**
Small companies	1.4579	2.3636	162.1236
Medium-sized companies	1.4807	2.3864	161.1670
Large companies	1.7935	2.6992	150.4990

Both of these pieces of information are beneficial not only for energy industry regulators, but also for potential investors. Strategic plans focus on the appropriate ratio of renewable and non-renewable resources, but do not address the productivity of companies that will produce this energy. As mentioned above, this market sector consists mainly of small and medium-sized enterprises. But these enterprises have lower productivity. These findings could motivate companies to cooperate more towards greener electricity generation.

A detailed analysis of state subsidies provided could also be very beneficial. The differing effect of subsidies on the performance of companies has already been demonstrated in the agricultural sector; see for example Galanopoulos et al. (2011). If subsidies in the energy sector are distributed unevenly in terms of company size, then the state can indirectly support but also reduce differences in companies' productivity.

5 CONCLUSIONS

This article provides indicative evidence that despite the EU's efforts in the energy sector the use of renewable energy sources negatively affects the total product of the sector. In addition to differences in productivity from the perspective of individual countries, there are also statistically significant differences in the value of technological progress with respect to company size. In the future, however, it is possible to expect more intensive convergence of national electricity generation sectors. And differences between countries could therefore be reduced.

Estimates of the parameters of the elasticity of output to input factors in selected models indicate that in terms of production in the electricity sector, capital has a greater influence on the size of the product compared to labor. The smaller influence of the labor factor can probably be attributed to the high automation of the electricity production process, where the workforce fulfills the function of supervision, maintenance, etc.

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